

PLIF in thoracolumbar trauma: technique and radiological results

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Abstract Patients with fractures from the 11th thoracic to the 5th lumbar vertebra had a reconstruction of the anterior column with monocortical iliac crest autograft by using a single dorsal approach. The loss of correction was observed using X-rays pre- and post-operatively, at 3 months and after implant removal (IR). Successful fusion was assessed using computed tomography after the implant removal. To assess the loss of correction and intervertebral fusion rate of this technique. There are still controversial discussions about the treatment modalities of spine lesions, especially in cases of burst fractures. Dorsal, combined and ventral procedures are reported with different assets and drawbacks. We want to present a method to restore the weight-bearing capability of the anterior column using a single dorsal approach. From 2001 to 2005, a total of 100 patients was treated with this technique at our department. Follow-up examination was possible in 82 patients. The X-rays and CT scans were proofed for loss of correction and fusion rate. The anterior column has been restored using a monocortical strut graft via a partial resection of the lamina and the apophyseal joint on one side to access the disc space. The dorsal reduction has been achieved using an angular stable pedicle screw system. The mean follow-up time was 15 months (range 8–39); 67 patients had a CT scan at follow-up and 83% showed a 360° fusion. The average post-operative loss of correction was 3.3° (range 0–21). The average duration of operation was 192 min

(range 120–360) and the mean blood loss was 790 ml (range 300–3,400 ml). Regarding the complications we did not have any deep wound infections. We had two epidural haematomas postoperatively with a neurological deterioration that had to be revised. We were able to decompress the neurological structures and restore the weight-bearing capability of the anterior column in a one-stage procedure. So we think that this technique can be an alternative procedure to combined operations regarding the presented radiological results of successful fusion and loss of correction.

Keywords Burst fracture · Single posterior approach · PLIF/TLIF technique · Intervertebral fusion

Introduction

The management of traumatic thoracolumbar fractures is still controversial [1, 10, 13, 20, 29, 36, 37, 45] especially in A3 burst fractures according to Magerl et al. [26]. If there is an impairment concerning the weight-bearing capacity of the anterior column, instability against flexion distraction or rotational forces or in presence of neurological deficits, surgical treatment is deemed to be necessary [9, 20, 21, 30–32, 36]. Various surgical techniques such as posterior stabilisation alone over anterior alone to combined procedures are described. The short-segmented posterior internal fixator is still considered the gold standard device for reduction and stabilisation. But without additional treatment of the anterior column, in many cases a significant loss of correction and/or implant failure has been observed. Whitesides [44] in 1977 has already mentioned that single dorsal fusion in unstable vertebral body fractures with or without ligamentous instability may fail

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and recommended the support of the anterior column via an anterior approach using the ribs, fibula or tricortical ilium as strut graft.

To minimise secondary kyphosis, Daniaux [6] bone-grafted the broken vertebra via one or two pedicles with a funnel. Since the intervertebral disc space plays a large role in post-operative loss of correction, the disc was partly resected and the intervertebral space filled with bone chips [6, 7]. Whenever the spinal canal had to be cleared, the cancellous bone was introduced into the intervertebral space via an open approach similar to the PLIF or TLIF [5, 15] technique in degenerative spine diseases. The results presented by Daniaux could not be reproduced by others [20, 21, 41, 43]; therefore we modified the original technique.

We present a method for stable reconstruction of the anterior column following trauma using corticocancellous strut grafts. The grafts are put into place by a posterior approach in addition to transpedicular fixation.

Materials and methods

From 2001 to 2005 a total of 319 patients with fractures of the thoracolumbar spine was treated operatively at our department; 100 consecutive patients were treated with this technique and data were collected prospectively to evaluate the radiological loss of correction and the rate of successful intervertebral fusion.

Follow-up examination was possible for 82 patients; 18 patients could not be traced as they were tourists from countries other than Austria.

According to our protocol, all patients had AP and lateral X-rays as well as a CT-scan of the injured spinal levels pre- and post-operatively, 3 months following trauma and a follow-up X-ray at the time of the implant removal (IR) or at a minimum of 8 months following trauma; 67 patients had also a CT-scan after IR to assess the intervertebral and dorsal fusion. The fractures were classified according to Magerl et al. [26]. On the lateral X-rays, monosegmental angles were measured according to the Spine Working Group of the German Society of Trauma Surgery [22, 34] (Fig. 1). A minus means kyphotic and a positive means lordotic. The narrowing of the spinal canal was measured on the axial CT scans and described in percentages as compared to the width of the adjacent intact vertebra. Fusion was defined by using the criterion of McAfee et al. [27]. Complete bony bridging between the endplates was classified as ‘fused’; radiolucent areas between the graft and one endplate were classified as ‘partially fused’; and radiolucent areas around the graft or graft resorption were classified as ‘non-fused’. Concerning the posterior fusion, we differentiated ‘fused’ from ‘non-fused’ patients.



Fig. 1 Segmental angle was measured between both endplates adjacent to the fused segment in the lateral view

The American Spinal Injury Association (ASIA) impairment scale was used to classify the neurological status.

We enrolled patients with unstable spine injuries from Th11 to S1 that resulted in a reduced load-bearing capacity of the anterior spinal column caused by vertebral burst fractures (AO-Type A3) and injuries to the ligaments and the intervertebral disc (AO-Type B and C).

During these years this technique was commonly used by our spine team of six experienced surgeons.

As an implant, an internal fixator (USS™ Pedicle Screw System, Synthes Medical, Oberdorf, Switzerland) was used in all the cases. In the first 2 years we did monosegmental instrumentations, whenever we were able to insert the screws outside the fracture zone. Retrospectively seen this means “little comminution” according to McCormack et al. [28]. After this period we changed to bisegmental instrumentations as standard procedure, because we have seen that patients with a loss of correction $> 10^\circ$ ($n = 4$) were treated monosegmentally.

Statistics

SPSS 15.0 (SPSS, Chicago, IL, USA) was used for statistical analysis. For independent samples, a *t* test for independent samples or a non-parametric Mann–Whitney test was performed. For paired samples, a paired *t* test or a non-parametric Wilcoxon test was used. The Kolmogorov–Smirnov test was

used for determination of the distribution form. The probability level was set at $p < 0.05$.

Surgical technique

The operation is performed in the prone position. The dorsal elements of the injured section are exposed via a standard dorsal midline approach. We always try to preserve the medial branch of the Ramus dorsalis n. spinalis in order to minimise damage to the trunk muscles [2]. Therefore, we do not dissect as far as the lateral border of the apophyseal joints. A pair of screws is inserted into the vertebral bodies.

In the next step, we harvest monocortical strut grafts from the posterior iliac crest. Now the supra- and interspinal ligaments are resected. With an interlaminar spreader placed at the base of the adjacent spinous processes the ligamentum flavum is stretched and carefully resected along the midline to both sides. Then a partial laminectomy of the cranial and caudal lamina is performed on one side. For the levels L3–S1 we extend the approach to the superior articular process and resect the lower part of the inferior articular process of the upper vertebra. At the thoracolumbar junction the articular processes have to be resected completely in order to access the disc space via the foramina (Fig. 2).

In both cases the dural sac is identified and carefully retracted no further than the midline in the lumbar region and only a few millimetres in the thoracolumbar junction in order to coagulate epidural veins. The disc space and the retro-pulsed bony fragment are identified. Dural tears should be closed directly after they are detected. The

posterior wall fragment can now be pushed forward to decompress the dural sac. In most cases a complete reduction with the push-back technique fails because the disc material protrudes in the central defect of the fractured vertebra, or because of the trapezoidal shape of the posterior wall fragment.

The discus intervertebralis is incised and the destroyed tissue can be removed with rongeurs and curettes. A thin layer of the cortical endplate is removed with straight and curved osteotomes to achieve the best conditions for the bony fusion.

The posterior wall fragment can now be pushed into the intervertebral space and then be resected, or it may be reduced by pressure with a special L-shaped instrument into the broken vertebral body until the dural sac is decompressed.

To optimise the access area to the intervertebral disc space, the dorsal rim of the vertebral body should be resected. In transforaminal cases, the upper part of the pedicle should also be removed (Fig. 2b). The anterior part of the disc space is now filled with cancellous bone. The monocortical bone blocks are shaped and tapped in. If there is a remaining central defect, the blocks can be inserted longitudinally. Alternatively, the defect can be filled with cancellous bone chips and a horizontally placed block. The strut graft must be placed completely inside the disc space to avoid compression of the spinal nerve roots. The position of the bone blocks can be checked under direct visualisation and via an image intensifier in the lateral projection.

The interlaminar spreader is removed and mounting the longitudinal bars between the screws at each side finishes

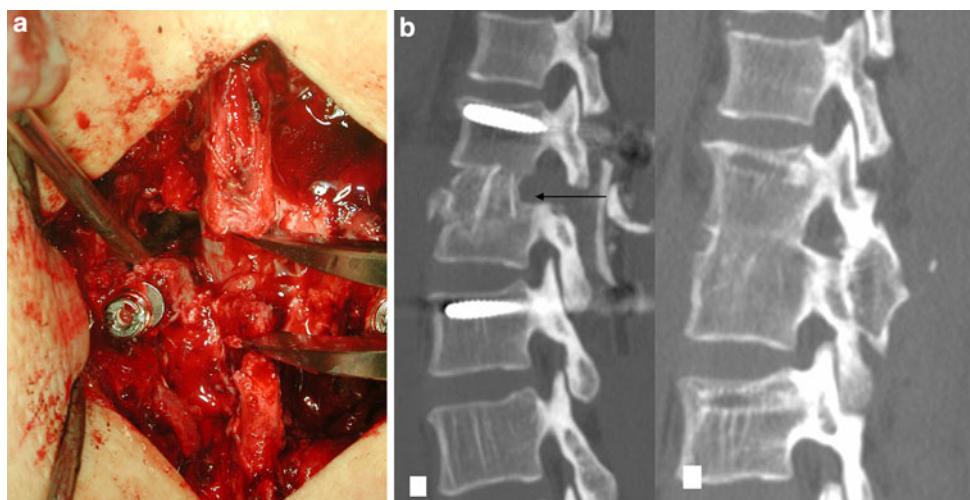


Fig. 2 **a** Intraoperative photo shows the interspinal spreader in position. The transforaminal approach to the disc space is lateral to the dural sac. **b** An incomplete cranial burst fracture (A3.1.1) of L1 is instrumented bisegmentally. The arrow shows the transforaminal approach with resection of the upper articular process and the

posterior rim of the vertebral body. The monocortical bone graft is brought in, in longitudinal direction and shows good contact with the endplates. CT scan after the IR shows successful intervertebral and posterior fusion with satisfactory alignment

the instrumentation. Slight posterior shortening and compression of the posterior elements can now be carried out in order to get good contact between the grafts and the vertebral endplates and also to create the desired amount of reduction and lordosis. The position of the graft and the decompression of the spinal canal should now be re-checked with a small dissector.

Finally, we perform an interspinal and interlaminar spondylodesis as described by Daniaux [6] and Daniaux et al. [7].

If drainages are used, they are removed on the second day post-operatively and the patient is mobilised without any brace (Fig. 2).

Results

The average age at the time of trauma was 33 years \pm 13 (range 16–69). There were 62 male and 20 female patients. The reasons for trauma included a fall from height in 31 cases; skiing or snowboard accidents in 29 cases; paragliding accidents in 9 cases; traffic accidents in 12 cases; horse-riding accidents in 4 cases, and direct trauma in 1 case. The distribution of the fractures according to the spinal level shows a peak at the thoracolumbar junction (46 of 82); 36 patients had a fracture below L1. According to the AO classification of Magerl et al. [26] there were 55, A3 fractures; 19, B-lesions; and 7, C-lesions. The type B and C injuries were all associated with burst fractures of the vertebral body. There were 26, A3.1; 49, A3.2; and 7, A3.3 fractures.

Neurological deficits were detected in 21 cases. There were four patients with complete paraplegia (Frankel A), one with Frankel B, five with Frankel C, six with Frankel D, and five with radicular deficits. The patients with Frankel A did not improve, but those with radicular deficits resolved post-operatively. The group with incomplete lesions improved at least one Frankel grade.

The mean time between accident and operation was 3.4 days (range 0–28). The mean follow-up was 15.5 months (range 8–39; $n = 82$).

The average time in surgery was 192 min (range 120–360; median 180), and the mean blood loss was 790 ml (range 300–3,400 ml; median 500 ml).

The PLIF procedure was done only monosegmentally, i.e., in the most severe injured motion segment.

Forty-six patients were instrumented bisegmentally, 32 monosegmentally and 4 had trisegmental instrumentation due to two-level fractures.

The post-traumatic monosegmental kyphosis in 82 patients measured on admission was $-11.3^\circ \pm 10.3^\circ$. The post-operative monosegmental angle was $3^\circ \pm 7.4^\circ$. At the time of the IR the average monosegmental angle was

$-0.3^\circ \pm 7.7^\circ$. Consequently the loss of correction is $3.3^\circ \pm 3.7^\circ$ (range 21.2° – 0°), i.e., 23% of the initial reduction (Fig. 3).

Sixty-seven patients had an IR and CT scan; 11 patients had only an IR without CT scan. Four patients did not have an IR. This was due to complete paraplegia in two cases; due to an age of 65 years in one case; and one is refusing surgery despite an age of 35 years. In cases of bisegmental instrumentation but monosegmental fusion, we recommend removal of the implant to restore motion to the additional fixed-motion segment.

In 56 of 67 patients with a CT scan after IR we could demonstrate an anterior interbody fusion (Fig. 4). In six patients there was a partial fusion and in four cases the implanted graft has been resorbed. In only one patient the posterior fusion failed.

The cases with fusion loss $2.9^\circ \pm 3.6^\circ$ and those without anterior fusion loss $3.5^\circ \pm 2.4^\circ$ ($p > 0.05$).

There was also no statistical difference in loss of correction between the fractures of the thoracolumbar junction ($3.3^\circ \pm 3.9^\circ$ and $3.4^\circ \pm 3.5^\circ$) and below the 2nd lumbar vertebra ($p > 0.05$). The monosegmental angle at the time of IR was on average $-2.7^\circ \pm 6.4^\circ$ (range 8° to -15°) for fractures of the thoracolumbar transition (Th11–L2), and $8.1^\circ \pm 6^\circ$ (range 0° – 23°) for L3–S1.

Patients with monosegmental instrumentation ($n = 32$) lost $4.1^\circ \pm 5^\circ$ and those with bisegmental instrumentation lost $2.9^\circ \pm 2.5^\circ$, but there is no statistical difference ($p > 0.05$).

Concerning fusion and instrumentation, no statistical difference could be found ($p > 0.05$).

The average narrowing of the spinal canal was 38% (range 0–100%). After the operative decompression, we could find a narrowing of 8% (range 0–40%) in relation to the width of the adjacent spinal canal.

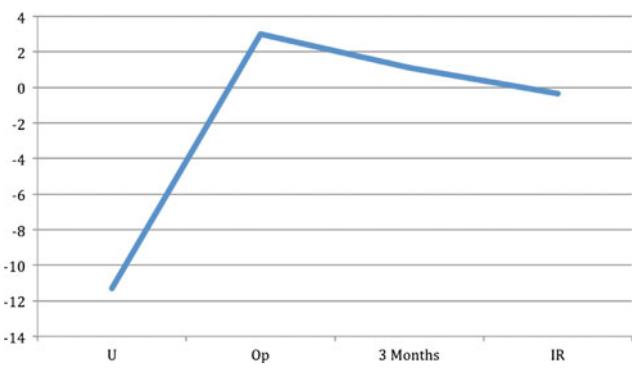


Fig. 3 The initial correction and the following loss of correction in diagram

Fig. 4 A 24-year-old male who had a fall from a height during the landing procedure in paragliding. He suffered a A3.2.1 fracture of the 2nd lumbar vertebra with horizontal fracture of the spinous process. The spinal canal is completely narrowed by a posterior wall fragment. On admission he showed a complete paraplegia that did not recover. The posterior fragment was resected and monocortical strut grafts were put in place. The patient was instrumented bisegmentally. The CT scan after IR showed successful intervertebral fusion. The loss of correction was 4.5°



Complications

In this series we did not have any deep wound infections. We observed two epidural haematomas postoperatively with a neurological deterioration that had to be revised. The neurological symptoms resolved during hospitalisation.

Discussion

As treatment strategies in spinal trauma are discussed controversially, goals of surgical techniques have to be defined very clearly. It should be possible to decompress the neural tissue, facilitate neurological recovery, restore the spinal alignment and prevent loss of correction with

neurological impairment. Short instrumentation and high fusion rates are favourable.

Furthermore it should allow rapid mobilisation and rehabilitation to decrease problems of long immobilisation.

Anterior or combined approaches with anterior decompression provide satisfactory decompression of the spinal canal, good reconstruction of the anterior column using tricortical strut grafts or cages and solid fusions. Biomechanical investigations have shown that anterior fusion provides superior stability as compared to single dorsal instrumentations [17, 19, 23, 35].

However, the operative risk of an anterior approach is higher than that associated with posterior approaches [10, 20] and single anterior fusions may fail in cases with disrupted posterior stabilising elements [39].

The presented method combines the reduction possibilities of dorsal instrumentation and weight-bearing capabilities of implanted cages or tricortical strut grafts via an anterior approach.

After mono- or bi-segmental posterior instrumentation we gain access to the anterior column via a partial hemilaminectomy and complete or partial resection of the apophyseal joint.

The intervertebral disc is removed. Posterior wall fragments narrowing the spinal canal can be pushed forward or removed. The intervertebral space is filled with cancellous bone and monocortical strut grafts.

This study aimed to prove the validity and reliability of the presented surgical technique concerning loss of correction, decompression of the spinal canal and fusion rate.

Our patient population is similar to other reports in distribution of gender, number of neurological lesions, distribution of fracture types and levels and reasons of injury [8, 13, 16, 26, 33]. However, our patients were younger than those reported by Reinhold et al. [33]. There is no obvious explanation for this phenomenon.

The initial reduction amounts to 14.3° and is similar to the results reported by Knop et al. [20] and Verlaan et al. [40].

The post-operative loss of correction in our study was 3.3° (range 0°–21°). This is comparable with the results of combined procedures reported by Knop et al. [20], Verlaan et al. [40], and Lange et al. [24]. We are aware of some more loss after the IR, but in cases with successful anterior fusion this should be moderate. Perhaps patients with partial fusion will fuse after the IR due to further loss of correction, so that there will be no more stress-shielding [18].

One patient lost 21° of correction. The lesion type was classified as B1.2.1 and the fracture type as A3.1.1. She was monosegmentally instrumented and there was no intervertebral fusion at the time of the IR. Three months after IR, a satisfactory intervertebral fusion was seen. The

dorsal fusion still failed. The screws in the fractured vertebra were located very close to the cranial endplate so that they became loose and therefore the whole construct was unstable and the incorporation of the strut graft was impaired. Therefore, in this case there was no stress-shielding but there was a mechanical irritation of the graft bed by the screws (Fig. 5).

The average monosegmental angles at the IR show lordotic values for the lumbar region and minimal kyphotic values for the thoracolumbar transition. Gelb et al. [12] report “indices of sagittal spinal alignment” with 2° to $-4^\circ \pm 5^\circ$ for the Th12–L1 and L1–L2 region. For the lumbar spine they report -10° to -24° .

The decompression of the spinal canal from 38 to 8% is effective. Esses et al. [10], reported about 58% in anterior cases and 44.5% in posterior cases with better results of decompression in the anterior group. Reinhold et al. [34] reported about an average post-traumatic narrowing of 34–42% and 9–19% post-operatively, with 19% in the single dorsal and combined group.

In cases with neurological deficits we prefer an immediate stabilisation and decompression in accordance with other authors [20, 24, 40].

In this series there was one patient who had a blood loss of 3,400 ml due to extensive bleeding of the fractured vertebra and torn epidural veins. This is one disadvantage of this method. So we carefully coagulate the epidural veins stepwise on the way through the spinal canal. Bleeding from the bone often suspends after reduction of a posterior wall fragment. In 2007 we had to stop an operation without strut grafting the anterior column due to extensive and non-stoppable bleeding. We finished the instrumentation and did an anterior procedure 1 week later.

In 83% of our patients with a CT scan after IR a 360° fusion could be verified. So the weight-bearing capacity of the anterior column is restored, which is an important goal

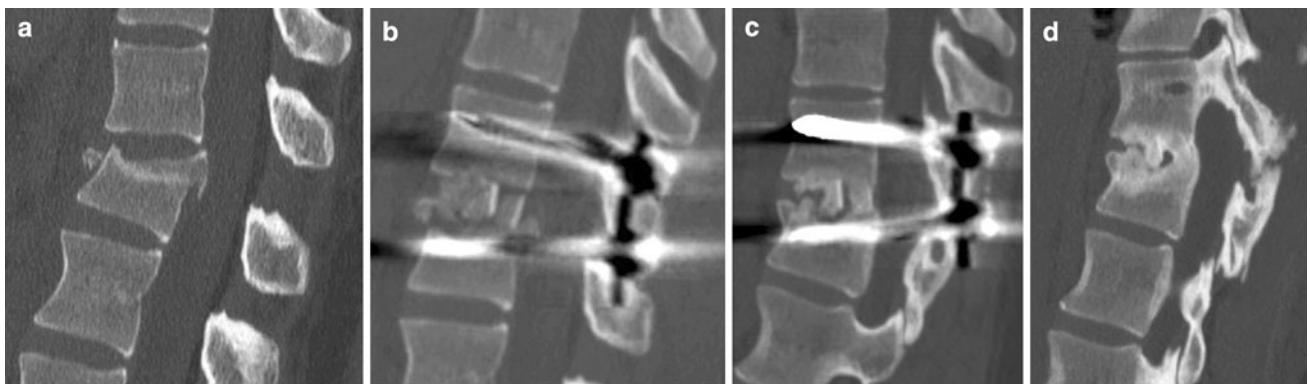


Fig. 5 A 25-year-old female who fell from a horse. She was neurologically intact. **a** and **b** CT scans showed an incomplete cranial burst fracture. The screws were set very close to the graft bed and the bone blocks did not have good contact with the endplates. **c** After a

superior loss of correction CT scans showed only partial intervertebral fusion. There was no sufficient fusion to the fracture area. **d** After IR there was an additional loss of correction and intervertebral fusion occurred in the posterior intervertebral area

according to several authors [7, 11, 14, 17, 19, 20, 24, 25, 29, 35, 36, 38, 40]. The six patients with a partial fusion showed the non-fusion area between the graft and the fractured endplate. Perhaps this is due to necrosis of the crushed cancellous bone or the intruded disc material. Those results are similar to the reports of Knop et al. [20] after reconstruction of the anterior column via a ventral or combined approach. Briem et al. [3, 4] reports anterior fusion rates of 77 and 65%. Lange et al. [24] reports 83% of anterior intervertebral fusion as diagnosed by X-rays. Dickman et al. [8] refers to 95–99% fusion rates in a meta-analysis, but several of the studies he included did not define fusion criteria.

We still perform posterior fusions with autogenous bone from the iliac crest although this is controversial [42]. In PLIF/TLIF cases we must remove posterior stabilising elements to gain access to the disc. The attendant loss of stability must be addressed concurrently. This can be considered a “second line of defence” to prevent further instability and deformity if the ventral fusion fails.

Conclusion

With this technique it is possible to decompress the neurological structures and to restore the anterior column in a one-stage procedure in emergency cases as well as in elective operations. The monosegmental angles at the time of IR seem to be close to physiological. The attained fusion rates are similar and sometimes better than reported with combined procedures. Thus, we think that this technique can be an alternative procedure to combined operations regarding the presented radiological results of successful fusion and loss of correction for A3.1–A3.2 fractures. In cases of A3.3 fractures we would prefer a combined procedure with a bisegmental vertebral body replacement and bisegmental dorsal biological fusion and instrumentation.

A disadvantage of this study is the lack of biomechanical data concerning the anterior stability gained by an autologous bone graft.

In further studies we will have to prove whether there would be any further loss of correction after IR. Also, subjective reports from the patients should be considered.

Key points

- It is possible to successfully restore the weight-bearing anterior column using monocortical strut graft via a dorsal approach.
- Sufficient clearing of the spinal canal is possible.
- Fusion rates and post-operative loss of correction of this method are comparable with combined antero-posterior procedures.

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